SVENSKA KRAFTNÄT

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TECHNICAL GUIDELINE

REVISION
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APPROVED
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Substations, Bolted connectors for current carrying conductors in outdoor substations

Introduction

This document in English shall be regarded as a translation of the corresponding guidelines in Swedish. The aim of the translation is to provide support to foreign manufacturers. The wording in Swedish and the interpretation thereof shall govern contract and legal relations between the parties of the purchasing process.

These guidelines describe the requirements on bolted connectors with limited tensile strength in order to connect current carrying connectors for outdoor substations ad deals with design and inspection. The guidelines intend to ensure that the bolted connectors give a satisfactory function during the calculated technical lifetime for the substation and shall be used at purchase of bolted connectors.

Notes	Change notes	Date

Content

1 References

Note that standards, regulations etc. which are referred to in these guidelines are subject to continuous change and can be withdrawn, revised or replaced. It is the obligation that the contractor immediately will inform the client of such changes.

ISO 4015	Hexagon head bolts -- Product grade B -- Reduced shank (shank diameter approximately equal to pitch diameter)
SEN 211011	Flat terminals
SEN 211012	Cylindrical terminals
SS 1964	Threaded blind holes - ISO metric screw threads - Coarse pitch
SS 2173	Diameters of spot facings, counter-bores and countersinks - Screws and nuts with ISO metric screw threads and tapping screws
SS-EN 9001	Quality management systems - Requirements
SS-EN 10002-1	Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature
SS-EN 60865	Short-circuit currents - Calculation of effects - Part 1: Definitions and calculation methods
SS-EN 61284	Overhead lines – Requirements and tests for fittings
SS-EN ISO 887	Plain washers for metric bolts, screws and nuts for general purposes - General plan (ISO 887:2000)
SS-EN ISO 1302	Geometrical Product Specifications (GPS) - Indication of surface texture in technical product documentation
SS-ISO 4287-1	Geometriska produktionspecifikationer (GSP) - Ytstruktur: Profilmetod - Termer, definitioner och parametrar för ytstruktur (ISO 4287:1997)
SS-EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles -- Specifications and test methods
SS-EN ISO 7089	Plain washers - Normal series - Product grade A
SS-EN ISO 3506-1	Mechanical properties of corrosion-resistant stainless-steel fasteners - Part 1: Bolts, screws and studs
SS-EN ISO 3506-2	Mechanical properties of corrosion-resistant stainless-steel fasteners - - Part 2: Nuts
SS-EN ISO 4017	Fasteners - Hexagon head screws - Product grades A and B
SS-EN ISO 4032	Hexagon regular nuts, style 1 - Product grades A and B
SS-EN ISO 6506-1	Metallic materials - Brinell hardness test - Part 1: Test method
SS-EN ISO 6507-1	Metallic materials - Vickers hardness test - Part 1: Test methodSS-ISO 272 Fasteners -- Hexagon products -- Widths across flats
SS-ISO 1101	Technical drawings - Geometrical tolerancing - Tolerancing of form, orientation, location and run-out - Generalities, definitions, symbols, indications on drawings
SS ISO 2178	Non-magnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method

EBR U303K	Maintenance overhead lines 0,4 – 420 kV
SvK TR 05-04E	Technical guidelines – Conductors
SvK TR 08E	Technical guidelines – Documentation

2 Scope

These guidelines describe the requirements on bolted connectors with limited tensile strength in order to connect current carrying connectors for outdoor substations and deals with design and inspection. The guidelines intend to ensure that the bolted connectors give a satisfactory function during the calculated technical lifetime for the substation and shall be used at purchase of bolted connectors.

SS-EN 61284 has been taken into consideration during the establishment of these guidelines. The standards requirement has been studied and analysed when it has shown that it do not give enough level against deterioration of the current carrying capacity for the lifetime of the substation. This has resulted in that this guideline has received this outline.

These guidelines are written in Swedish and English. If differ, the text and conditions given in Swedish version are the ruling ones.

3 Definitions

Technical terms and definitions used in these guidelines:

Current carrying part

Part of the bolted connector that carries the current between the different connected conductors.

Keeper

Part of bolted connector clamping the conductor against the current carrying part

Highest voltage for equipment-U_m

The highest phase-to-phase voltage for which the equipment is designed. The highest voltage for equipment is designated U_m in this document.

Corona extinction voltage

The voltage where no corona (including the negative part) is visible when the voltage is reduced from a level with visible corona.

Fault current

The highest short time current which is caused by either a short-circuit (Ik) or earth fault (3I0)

4 Description

Bolted connector

Arrangement constitute of multiple parts of bolted connectors in order to carry electrical connection between two or multiple conductors where contacts is achieved between the installed conductors

Parallel grove clamps

Bolted connector for connection between conductors wrapping over each other. See Figure 1

T-connector

Bolted connector for connection between main connector and branch connector. See Figure 2

Flexible connector

Momentum free bolted connector to create connection between two main conductors consisting of tubes or between tube and apparatus terminal.

5 Requirements

5.1 General

Bolted connectors shall be able to withstand the mechanical stresses which can occur during transport, handling and installation at temperatures as low as -40 °C, in addition to the mechanical stresses which can occur during the lifetime of the overhead line at temperatures from -50 °C to +100 °C.

5.2 Material

5.2.1 General

The material shall be resistant to atmospheric influences and corrosion. All material used shall keep good mechanical and electrical properties and high tenacity at all temperate down to -40 °C.

5.2.2 Aluminium

Connectors shall be manufactured from aluminium alloy. The alloy, which shall not contain more than 0,1 % Cu, shall not be liable to stress corrosion cracking or layer corrosion.

Cast and wrought aluminium shall fulfil the requirements relating to tensile strength, hardness and resistivity as specified in Table 9.

For aluminium in flexible conductors as is a part of flexible connectors is no prescription stated.

5.2.3 Steel

Bolts and nuts shall be made of stainless or acid proof steel and fulfil the requirements for A2-80 or A4-80 in accordance with SS –EN ISO 3506-1 and SS –EN ISO 3506-2.

Washers and thread inserts shall be made of stainless steel, and shall have at least the same resistance to corrosion as steel grade A2 in accordance with SS-EN ISO 3506-1. Between the screw heads and nuts as will be tightened during installation shall be plane washers. Washers shall be in accordance with SS-EN ISO 887 and SS-EN ISO 7809.

Other steel parts may be made of non-stainless steel but shall be hot-dipped galvanised in accordance with SS-EN ISO 1461.

5.2.4 Non-metallic materials

Non-metallic materials shall have good resistance to ageing and be capable of withstanding temperatures between -50 C and +200°C without change of essential properties. Materials shall have adequate resistance to the effects of ozone, ultra-violet radiation and air pollution over the entire temperature range.

6 Design

6.1 General

Connectors shall be able to withstand the mechanical stresses which can arise during transport, installation and operation.

Connectors shall be easy to install without the use of special tools.

Connectors should be able to install on stranded conductors, which have been in operation for many years. In the event of reinstallation, connectors should be able to install on stranded conductars in the same position as before that. In the event of replacement, connectors should be able to install on stranded conductors in the same position in which other connectors have previously been installed.

Connectors shall be so designed that water collection is eliminated. If this is not possible, they shall have drainage holes with a minimum diameter of 6 mm. Further requirements, as specified in 7.6, apply for flexible connectors.

Permanent deformations, cracks or failures shall not occur in connectors for bundled stranded conductors as the result of conductor clash in the event of short-circuit.

Connectors intended to connect single and twin bundled stranded conductors to flat terminals shall be so designed that the connectors can be installed on a flat bar which is parallel to the stranded conductors unless the terminal of the apparatus is oriented in different direction.

Connectors intended to connect triplex conductors to flat or cylindrical terminals or tubes shall be so designed that two conductors will be connected on one side and one connector on the other side of the terminal in such a way that the conductors forms an equilateral triangle.

Surfaces of connectors shall not be treated with the intension of increasing the coefficient of emission.

6.2 Conductor grooves

6.2.1 Conductors

The connectors shall have a conductor groove for each conductor. Each groove shall be suitable for the conductors having the same external diameter as specified in SvK TR05-04E respectively Annex A and Annex C in this guideline given conductors in order to that any of the conductors with the same diameter can be installed in the connectors without causing permanent deformation in the connector. The centre-centre distance between bundled conductors shall be between 80 mm to 100 mm. Unless otherwise specified or agreed triple bundled conductors shall be arranged at the apexes of an equilateral triangle. Conductor groove lengths shall be as specified in Tables 1 to 5. Conductor grooves shall be so designed that they do not reduce the strength of the conductors. The edges of conductor grooves, ***G*** in accordance with Figures 9 to 11, shall be rounded, with a minimum radius of 1 mm. The ends of conductor grooves, ***K*** in accordance with Figures 9 to 11, shall be rounded with a minimum radius of 2 mm. Conductor grooves for stranded conductors terminating in the connectors shall be

provided with a notch for locking the ends of the stranded conductor. This notch shall have a minimum length of 8 mm and a minimum depth of 2 mm.

6.2.2 Tubes and cylindrical terminals

The connectors shall have a conductor groove for each conductor. Each groove shall be suitable for those conductors specified in Tables 3 and 5 to 8 with the same external diameters as any of the conductors with the same diameter can be installed in the connectors without causing permanent deformation in the connector. Conductor groove lengths shall be as specified in Tables 3 and 5 to 8. Conductor grooves shall be so designed that they do not reduce the strength of the conductors. The edges of conductor grooves, ***G*** in accordance with Figures 9 to 11, shall be rounded, with a minimum radius of 1 mm. The ends of conductor grooves, ***K*** in accordance with Figures 9 to 11, shall be rounded with a minimum radius of 2 mm.

6.2.3 Flat terminals

Connectors contact surface for flat terminals shall match the terminals according to Annex B and meet the requirements in Clause 6.5. Connection shall be able on either side of a terminal.

6.2.4 Cylindrical terminals

Connectors contact surface for cylindrical terminals shall match the terminals according to Annex C and meet the requirements in Clause 6.5.

6.3 Current-carrying parts and keepers

Current-carrying parts of the Connectors shall be cast or forged in one piece. Connectors intended for connection of parallel stranded conductors shall consist of two Current-carrying parts. Bolts shall be positioned between the conductor grooves. Connectors shall have the number of screws as specified in Table 1.

Connectors with keepers shall have the number of keepers in accordance with Tables 2 to 6. Each keeper shall have two screws. The screws shall be positioned on each side of the conductor groove.

Connectors intended for connection of tubes may consist of two current-carrying parts. Bolts shall be similarly positioned on both sides of the conductor groove.

For flexible connectors are special requirements applicable in accordance with Clause 6.4.

6.4 Flexible connectors

Flexible connectors shall fulfil requirements relating to size, angular adjustment, movements and forces as specified in Clause 7.6

Flexible connectors shall impose the least possible tensile, torsion and bending forces on terminals under both normal operating conditions and short-circuit conditions. Connectors shall be so designed that tubes cannot fall out of them.

In connectors for connecting horizontal tubes and horizontal flat terminals shall the tubes be positioned above terminals unless otherwise is specified. In connectors for connecting horizontal tubes and vertical cylindrical terminals shall the tube be placed above the terminal unless otherwise is specified. In connectors for connecting horizontal tubes and horizontal cylindrical terminals shall the longitudinal axes of tubes and terminals shall coincide unless otherwise specified.

Flexible connectors shall have the least possible number of current connections. Such connections shall be welded by MIG-method or equal method. Cavities in welded interfaces may be filled with corrosion protecting grease. Short-circuits shall not give rise to permanent deformations, cracks or failures of the connectors. However, permanent deformation of flexible parts can be accepted if such deformation does not affect the function of the connectors. Electric current shall not be carried by the mechanical bearing parts, whether during normal operation or during short-circuits. Arcs shall not be established during short-circuits. Tubes shall be so supported that it is not possible for a direct impact to arise between a tube and terminal in the event of short-circuit.

6.5 Contact surfaces

Current-carrying contact surfaces on cast aluminium shall be machine finished and free from casting skin. Current-carrying contact surfaces on forged aluminium do not need to be machined. Current-carrying contact surfaces in conductor grooves for stranded conductors shall have a surface smoothness of Ra min N8 in accordance with SS-EN ISO 1302. The Contact surfaces may be transversely furrowed but the depth of such furrows shall not exceed 1 mm. Contact surfaces in keeper shall be smooth.

Current-carrying contact surfaces in conductor grooves for tubes and cylindrical terminals shall have a surface smoothness of Ra min N8 in accordance with SS-EN ISO 1302.

Current-carrying contact surfaces on terminal tongues shall have a surface smoothness of Ra min N8 in accordance with SS-EN ISO 1302.

6.5.1 Bolted connectors with two current carrying parts

Parallel groove clamps and connectors for cylindrical terminals and tubes shall have contact surfaces in accordance with Tables 1, 7 and 8. Current carrying surface, see Figure 9, are calculated accordingly:

$$A = [\pi D - 2(D - 2S) - 4G](L - 2K) - U$$

where:

A = Current carrying surface in the conductor groove [mm²]
D = Conductor diameter in accordance to SvK TR 05-04E, SEN 211012 or Annex A and Annex C in this guideline [mm]
G = Nominal radius of the conductor groove edges [mm]
K = Nominal radius of the conductor groove ends [mm]
L = Nominal length of the conductor groove [mm]
S = Nominal depth of the conductor groove [mm]
U = Combined area of notches in the groove as reduce the contact surface [mm²]
Note: The nominal size is the mean value of the low and high limits

6.5.2 Bolted connectors with keepers

Connectors with keepers shall have contact surfaces in accordance with Tables 2 to 6. Current carrying surface, see Figure 10, are calculated accordingly:

$$A = \left[0.5\pi D - 2\left(0.5D - S\right) - 2G\right]\left(L - 2K\right) - U$$

where:

A = Current carrying surface in the conductor groove [mm²]
D = Conductor diameter in accordance to SvK TR 05-04E, SEN 211012 or Annex A and Annex C in this guideline [mm]
G = Nominal radius of the conductor groove edges [mm]
K = Nominal radius of the conductor groove ends [mm]
L = Nominal length of the conductor groove [mm]
S = Nominal depth of the conductor groove [mm]
U = Combined area of notches in the groove as reduce the contact surface [mm²]
Note: The nominal size is the mean value of the low and high limits

6.5.3 Keepers

Keepers shall have contact surfaces in accordance with Tables 2 to 6. Current carrying surface, see Figure 11, are calculated accordingly:

$$B = \left[0.5\pi D - 2\left(0.5D - T\right) - 2G\right]\left(M - 2K\right)N - U$$

where:

B = Contact surface in the conductor groove of keeper [mm²]
D = Conductor diameter in accordance to SvK TR 05-04E, SEN 211012 or Annex A and Annex C in this guideline [mm]
G = Nominal radius of the conductor groove edges [mm]
K = Nominal radius of the conductor groove ends [mm]
M = Nominal length of the conductor groove [mm]
N = Number of keepers for each conductor
T = Nominal depth of the conductor groove [mm]
U = Combined area of notches in the groove as reduce the contact surface [mm²]

Note: The nominal size is the mean value of the low and high limits

6.6 Screws and nuts

Screws, nuts and washers should be captive in the clamps, in order to simplify hot line working.

The connectors shall be equipped with the number and dimensions of screws as specified in Tables 1-8.

Screw threads shall be M10 or M12.

Screws which are tightened during installation shall be in accordance with ISO 4015 or SS-EN ISO 4017. Nuts, which are tightened during installation, shall be in accordance with SS-EN ISO 4032. Other designs of bolt heads and nuts shall be approved by Svenska Kraftnät.

Screw heads and nuts shall be in accordance with SS-EN ISO 272. Other sizes of screw heads and nuts shall be approved by Svenska Kraftnät.

The screws shall be so long that they end outside the nut threads in the installed position.

Countersinks for tightening tools shall be in accordance with SS 2173.

6.7 Washers

Flat washers shall be fitted beneath screws and nuts which are tightened during installation. Washer dimensions shall be in accordance with SS-EN ISO 887 and SS-EN ISO 7089.

6.8 Threaded holes

Threaded blind holes shall have sufficient thread depth to ensure full tightening of bolts without bottoming. Threaded holes in cast aluminium in accordance with Table 9 shall be fitted with thread inserts. Threaded holes in forged aluminium in accordance with Table 9 shall be in accordance with SS 1964.

7 Mechanical requirements

7.1 Tightening torques

Tightening torques for screws and nuts shall be at least 45 Nm for M10 and at least 75 Nm for M12.

7.2 Threaded holes

Threaded holes shall have at least the same strength as A2-80 nuts in accordance with SS-EN-ISO 3506-2.

7.3 Washers

Washers shall have a hardness of HV min 200 at tests in accordance to SS-EN-ISO 6507-1

7.4 Contact force

The mean value for the pre-stressing forces in the screws shall for each separate conductor connection be 25 kN for M10 and 35 kN for M12 with respect to the difference in thermal expansion between aluminium and stainless steel at the tightening torques in accordance to Clause 7.1.

The connectors shall provide the contact forces specified in Tables 1 to 8. Contact forces are defined in Figures 12 to 14.

7.5 Deformation

Permanent deformation shall not occur in current carrying parts or keepers at a torque of 110% of the torque given in Clause 7.1.

7.6 Flexible connectors

Flexible connectors shall fulfil requirements relating to size, angular adjustment, movements and forces as specified below.

- The horizontal size of the connector, perpendicular to the longitudinal centreline of the tube, max 150 mm for the tube diameter 100 mm and 180 mm for tube diameter 150 mm. The dimension as specified refers to the distance from the centre line of the tube to the outer-most part of the connector.
  This dimension has been specified to permit the connection of tubes to different types of apparatus.
- Angular adjustment of the tube in relation to the connector, min 15°. The prescribed angle is the angle in any direction from a horizontal line parallel to the longitudinal axis of the connector to the centre line of the tube.
  This angle has been specified to permit connection of tubes between apparatus having different phase distances and elevations.
- Movement of the tube in the connector, min ±25 mm. The prescribed dimension relates to the movement of the tube in the longitudinal direction.
  This requirement has been determined to allow for the changes in length of the tube which can occur as a result of thermal expansion between the lowest temperature encountered during the winter and the highest temperature encountered after a short circuit.

- Force in the tube when the tube is moved 50 mm in the connectors in accordance with the previous, max 500 N. The prescribed force applies when the vertical force between the tube and connector is 1000 N.
  This requirement has been determined in order to permit an ice-coated tube to move in connectors without applying excessive forte to the apparatus terminals.
- Movement of the tube in the connector, ±10 mm. The prescribed dimension relates to daily movement of the tube in the longitudinal direction.
  This requirement has been determined in order to allow for the changes in length of the tube which can arise as a result of temperature changes between the minimum temperature encountered during the night and the maximum temperature encountered during the day, without giving rise to fatigue failure in the connectors.

Flexible connectors shall impose the least possible tensile, torsion and bending forces on terminals under both normal operating conditions and short-circuit conditions.

Flexible connectors shall not fail through fatigue, nor shall abnormal wear of tubes and connectors occur during operation. Tubes shall be so supported that it is not possible for a direct impact to arise between a tube and terminal in the event of short-circuit. Connectors shall not give rise to audible noise or UHF interference.

8 Electrical requirements

8.1 General

Permanent deformations, cracks or failures shall not occur in connectors for bundled stranded conductors as the result of conductor clash in the event of a short circuit. Surfaces of connectors shall not be treated with the intension of increasing the coefficient of emission.

8.2 Current carrying capacity

Bolted connector shall be able to carry the current given in Tables 1 to 8 without reaching a higher temperature then +70 °C at an ambient temperature of +30 °C. However the conductor is allowed to reach a temperature of +85 °C.

8.3 Corona

Bolted connector for phase conductor shall be free from visible corona at a test voltage, phase – earth of:

$$\text{Test voltage} = \frac{U_m}{\sqrt{3}} * 1{,}1$$

Where U_m is 245 kV and 420 kV respectively.

8.4 Resistance

Bolted connector for phase conductor shall have a resistance (R1) of maximum 80% of the resistance value for the same length of the conductor, measured from conductor to the conductor, in the vicinity of the connector.

8.5 Short circuit current

Bolted connector shall withstand a short-circuit current of 50 kA -1s without any deformation.

9 Type test

9.1 General

Type inspection relates to tests as described in Clause 9.4 - 9.10, intended to confirm and document that the connectors tendered fulfil the requirements of this technical specification.

Tests shall be carried out and paid for by the manufacturer. By agreement with Svenska Kraftnät, tests may be carried out by the manufacturer. Tests may be carried out indoors and at room temperature.

Unless otherwise prescribed, tests shall be performed on at least three (3) connectors, although this number may be reduced be agreement with Svenska Kraftnät. The tests shall be performed in such a manner that the test procedures or test equipment do not affect the results. Connectors consisting of parts which have already been tested, may be by agreement with Svenska Kraftnät, be partly or wholly approved without further testing.

9.2 Conductors

Stranded conductors shall be Al1 conductors according to SS-EN 50182 and SvK TR05-04E.

Tubes shall be according to Annex A in this guideline.

Terminals shall, if nothing else is stated, be round bars or flat bars of the same dimensions as the terminals according to SEN 211011 and Annex B respectively Annex C in this guideline.

9.3 Dimensions

The intention of this test is to check that the connector conforms to the requirements of Clause 6 and also that it is in accordance with the manufacturers drawing regarding measurements.

9.4 Contact forces

This test is intended to document that the connectors fulfil the requirements of Clause 7.4 in respect of contact forces.

Contact forces shall be measured for three successive installations, and may be measured by the means of a load cell.

Contact forces in connectors consisting of two current-carrying parts in accordance with may be measured for one bolt and one conductor groove at a time, see Figure 12. When carrying out the tests, a steel bar of the appropriate size may be fitted in the other conductor groove. When measuring contact forces for one bolt and one conductor groove at a time, the total contact force for each conductor groove will be given by the sum of the individual measured forces.

For connectors with keepers it is permissible for the contact forces to be measured for one keeper at a time, see Figure 13. The total contact force for each conductor groove will then be given by the sum of the individual measured forces.

The contact force for conductor groove shall exceed the contact forces specified in Tables 1 - 8 at all three installations. If the connectors are equipped with bigger bolts than are given in these tables the corresponding higher contact forces shall have been reached.

9.5 Deformation

This test is intended to document that the connectors fulfil the requirements of Clause 7.5 in respect of permanent deformations.

Connectors shall be installed and removed three times successively on Al1 conductors in accordance with SvK TR05-04E or Annex A in this guideline. New conductors shall be used for each successive installation.

Cylindrical terminals shall be manufactured of steel and have a diameter in accordance with SEN 211012 or Annex C in this guideline.

Tightening torques shall be 50 Nm for M10 and 83 Nm for M12 or 110% of what the manufacturer gives as tightening torque.

Deformation in the connectors shall be measured during testing. This can be done by means of strain gauges.

After completion of tests permanent set shall not exceed 0,15% in any part of the connectors. Reasonable impressions left by the conductors in conductor grooves will not be regarded as permanent deformations. Threaded joints shall not have jammed. After the test the contact forces shall be measured in accordance with clause 7.4.

9.6 Threaded holes

This test is intended to document that threaded holes in aluminium parts with or without threaded inserts fulfil the requirements of 7.2.

The screws shall be fitted in the threaded holes at minimum 15 mm for M10 respectively 18 mm for M12.

The screws shall be tension loaded in the axial direction of the screw with the test force of 45,2 kN for M10 and 65,6 kN for M12.

After completion of testing no failure of the threaded holes shall have arisen. It shall be easy to turn the screws freely with the fingers.

9.7 Washers

This test is intended to document that washers fulfil the hardness requirements of Clause 7.3.

Tests shall be carried out in accordance with SS-EN ISO 6507-1.

9.8 Flexible connectors

Functional test of flexible connectors

This test is intended to document that connectors fulfil the requirements of Clause 7.6 with respect to dimensions, angular adjustment, movements and forces.

9.8.1 Fatigue test of flexible connectors

This test is intended to document that connectors fulfil the requirements of Clause 7.6 with respect to daily movements resulting from temperature changes.

The tube shall be fitted so that the vertical forte on the mechanical joint between the tube and clamp is 400 N for 100 mm tube respectively 500 N for 150 mm tube.

The tube shall then be subjected to 30000 oscillations with a amplitude of ±10 mm in the longitudinal direction of the tube.

After testing, no cracks or failures in the connectors shall have a risen. Abnormal wear shall not have occurred in either the tube or the connector.

9.8.2 Temperature rise test of flexible connectors

This test is intended to document that connectors fulfil the requirements of Clause 8.2 with respect to continuous current loading.

Testing shall be carried out indoors at room temperature on two flexible connectors in condition as new.

The connectors shall be installed on appropriate conductors and shall be protected against undue external cooling.

Connections to the current circuit shall be made in such a way that no significant amount of heat is conducted away from the connectors during the test.

The test shall be carried out with a continuous current at a frequency of 50 Hz (frequency tolerance +20% and -5%) in accordance with Tables 6 and 7 with tubes in accordance with Annex A.

The test shall continue until steady-state conditions are achieved. For practical reasons, this state is regarded as having been reached when the rate of change of temperature is less than 1°C/h.

Connector temperature shall be measured by thermometers, thermocouple elements or other suitable means, applied to the hottest part of the connectors. Heat transfer between the surface of the connectors and the temperature-sensing devices shall be good.

Thermocouple elements or thermometer bulbs shall be protected in a suitable manner against external cooling.

9.8.3 Short-time current test of flexible connectors

This test is intended to document that the connectors fulfil the requirements of Clause 8.5 with respect to the mechanical forces which arise during a short circuit.

The test shall be carried out on two connectors.

The connectors shall be so arranged that the most severe conditions as are likely to be encountered in practice are simulated.

The connections for supplying current to the connectors shall be so arranged that the test results are applicable to operating conditions.

Testing shall be carried out in accordance with SS-EN 60865 so that the impulse value of the short-time current amounts to 2,55 times the RMS value.

The connectors shall be subjected to three (3) successive current surges of 50 kA for 1 second. Times exceeding 1 second are not permitted. Between each current surge, the connectors and conductor shall be allowed to cool, or be cooled to 40^0C or below. Any curvature of flexible conductors shall not be changed during testing.

If flexible connectors are capable of applying tensile, bending or rotational forces to apparatus terminals, such forces shall be measured.

The connectors shall complete the tests without cracking or failure. Deformation of flexible conductors in connectors can be accepted if such deformation does not affect performance of the connectors.

Arcing damage to the connectors or conductors shall not occur.

The connectors shall not apply excessive forces to apparatus terminals.

9.9 Corona

The intention of this test is to establish the corona extinction voltage and shall be performed in a fully darkened room. During the corona test the use of either field-glass with a minimum optical performance of 7x50 or an image intensifier with light amplification greater than 40000 in accordance with SS-EN 61284 is recommended.

The bolted connectors shall be installed on conductors according to SvK TR05-04E 0r tube according to Annex A in this guideline with a distance from energised phase to earth of 4,5 m for 245 kV respectively 5,0 m for 420 kV. The connectors shall be subjected to a 50 Hz voltage. Test apparatus in accordance with Figure 15 shall be used.

The corona extinction voltage level shall be higher than the test voltage specified in Clause 8.3 given voltage. The corona extinction voltage level shall be documented by colour photography's. One photo with visible corona and one at the corona extinction voltage. The voltage level shall be given on the photos.

The tests shall be performed in accordance to SS-EN 61284.

9.10 Resistance

This test is intended to document that the connectors fulfil the requirements of Clause 8.4 with respect to the resistance.

If the manufacturer recommends the use of contact paste at the installation it shall be used in the test.

10 Delivery

10.1 General

The client shall, according to these guidelines, approve the connector before delivery. On request form the client the manufacturer shall certify that inspection in accordance with Clause 10.2 have been carried out with approved results. For approval the manufacturer shall show that the connector conforms to these guidelines.

An approval of drawings do not exonerate the manufacturer from the responsibility that the bolted connector meets the requirements.

All documentation shall be written in Swedish or English.

10.2 Documentation

General requirements for documentation see SvK TR 08E. All documentation shall be handed over to Svenska Kraftnät before delivery.

10.2.1 Assembly drawing

The assembly drawing shall have a minimum of two views at an appropriate scale in accordance with SS-ISO 5455. On the drawing shall be given:

- Manufacturers trademark
- Type and/or catalogue number
- Conductor diameter
- Conductor groove length
- Rated operating current
- Rated short circuit current [kA, 1s]
- Maximal voltage for equipment -U_m [kV]
- All marking
- Weight
- List of components

10.2.2 List of material

Description of material in included parts.

10.2.3 Manufacturing process

Description of the manufacturing process.

10.2.4 Quality system

Quality system in accordance with SS-EN ISO 9001.

10.2.5 Installation instruction

Installation instructions in Swedish or English with the required figures.

10.2.6 Type test report

Type test report in accordance with Clause 9.

11 Installation

11.1 General

Installation shall be in accordance with the installation instruction

Current carrying parts, conductor groove and conductor, shall be treated in the following way at installation:

- Current carrying surfaces shall be brushed thoroughly with a steel brush.
- Contact paste shall be applied on the current carrying surfaces.
- The current carrying surfaces shall be brushed with a steel brush into the contact paste
- Additional contact past shall be applied

12 Tables

12.1 General

For current carrying bolted connectors Table 1-8 are valid.

For non current carrying bolted connectors the numbers of screws and keepers be may be reduced by one (1). However the remaining requirements in this guideline are valid in applicable pats.

12.2 Table 1 Bolted connectors with two current carrying parts to connect two parallel stranded conductors, see Figure 1

Conductor A			Conductor B						
Conductor designation area mm²	Current carrying surface A mm²	Contact force F kN	Conductor designation area mm²	Current carrying surface A mm²	Contact force F kN	Conductor groove length L mm	Screws N nos	Screw dimension	Current carrying capacity A
593	9800	70	593	9800	70	140	4	M12	1190
910	12000	70	593	9800	70	140	4	M12	1190
910	15000	87,5	910	15000	87,5	170	5	M12	1540

12.3 Table 2 Bolted connector with keepers for T-connection of stranded conductors. See Figure 2

Conductor A, main						Conductor B, branch							
Conductor designation Area mm²	Keeper N nos	Conductor groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Conductor designation Area mm²	Keeper N nos	Conductor groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Current carrying capacity A
593	3	115	4600	3300	150	593	3	115	4600	3300	150	M10	1190
910	3	115	5900	4300	150	593	3	115	4600	3300	150	M10	1190
910	4	155	8000	5800	200	910	4	155	8000	5800	200	M10	1540

12.4 Table 3 Bolted connectors with keepers for connection of stranded conductors to cylindrical terminals. See Figure 3

Stranded Conductor A							Cylindrical terminal B							
Conductor designation Area mm²	Keeper N nos	Conductor groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Terminal diameter mm	Keeper N nos	Groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Current carrying capacity A
593	3	115	4600	3300	150	M10	30	2	75	2700	2000	100	M10	1190
593	3	115	4600	3300	150	M10	40	2	75	3800	3000	100	M10	1190
593	3	115	4600	3300	150	M10	60	2	75	5900	4900	140	M12	1190
910	4	155	8000	5800	200	M10	30	3	115	4300	3000	150	M10	1250
910	4	155	8000	5800	200	M10	40	3	115	6000	4500	150	M10	1540
910	4	155	8000	5800	200	M10	60	2	75	5900	4800	140	M12	1540
2x593	2x2	75	2900	2200	100	M10	30	3	115	4300	3000	150	M10	1250
2x593	2x3	115	4600	3300	150	M10	40	3	115	6000	4500	150	M10	1600
2x593	2x3	115	4600	3300	150	M10	60	3	115	9400	7200	210	M12	2380
2x910	2x2	75	3700	2900	100	M10	30	3	115	4300	3000	150	M10	1250
2x910	2x3	115	5900	4300	150	M10	40	3	115	6000	4500	150	M10	1600
2x910	2x4	155	8000	5800	200	M10	60	3	115	9400	7200	210	M12	2500
2x910	2x4	155	8000	5800	200	M10	100	4	155	20000	15000	280	M12	3150

12.5 Table 4 Bolted connectors with keepers for connection of stranded conductors to flat terminals. See Figure 4

Stranded Conductor A							Flat terminal B			
Conductor designation Area mm²	Keeper N nos	Conductor groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Flat terminal designation mm	Holes N nos	Thickness T mm	Current carrying capacity A
593	3	115	4600	3300	150	M10	4-75	4	15	1190
593	3	115	4600	3300	150	M10	9-125	9	15	1190
910	4	155	8000	5800	200	M10	4-75	4	20	1540
910	4	155	8000	5800	200	M10	9-125	9	20	1540
2x593	2x3	75	2900	2200	100	M10	4-75	4	30	2380
2x593	2x3	115	4600	3300	150	M10	9-125	9	25	2380
2x910	2x3	115	5900	4300	150	M10	4-75	4	30	2500
2x910	2x4	155	8000	5800	200	M10	9-125	9	30	3150
2x910	2x4	155	8000	5800	200	M10	12-165	12	25	3150
3x910[1)]	3x4	155	8000	5800	200	M10	9-125	9	30	3150
3x910[1)]	3x4	155	8000	5800	200	M10	12-165	12	30	4000

1) Shall suitably be in accordance with clause 6.1

12.6 Table 5 Bolted connectors with keepers for connection of stranded conductors to tubes. See Figure 5

Stranded Conductor A							Conductor B, Tube							
Conductor designation Area mm²	Keeper N nos	Conductor groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Tube diameter mm	Keeper N nos	Groove length for tube L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Current carrying capacity A
593	3	115	4600	3300	150	M10	100	2	75	74000	2000	140	M12	1190
593	3	115	4600	3300	150	M10	150	2	75	110000	3000	140	M12	1190
593	3	115	4600	3300	150	M10	250	2	75	200000	4900	140	M12	1190
910	4	155	8000	5800	200	M10	100	2	75	74000	3000	140	M12	1540
910	4	155	8000	5800	200	M10	150	2	75	110000	4500	140	M12	1540
910	4	155	8000	5800	200	M10	250	2	75	200000	4800	140	M12	1540
2x593	2x3	115	4600	3300	150	M10	100	2	75	74000	3000	140	M12	2380
2x593	2x3	115	4600	3300	150	M10	150	2	75	110000	4500	140	M12	2380
2x593	2x3	115	4600	3300	150	M10	250	2	75	200000	7200	140	M12	2380
2x910	2x4	155	8000	5800	200	M10	100	2	75	74000	3000	140	M10	3150
2x910	2x4	155	8000	5800	200	M10	150	2	75	110000	4500	140	M10	3150
2x910	2x4	155	8000	5800	200	M10	250	2	75	200000	7200	140	M12	3150

12.7 Table 6 Flexible connectors with keepers for connection of tubes to cylindrical terminal. See Figure 6

Conductor A, Tube						Cylindrical terminal B							
Tube Diameter mm	Bolts N nos	Groove length L mm	Current carrying surface A mm²	Contact force F kN	Screw dimension	Terminal diameter mm	Keeper N nos	Groove length L mm	Current carrying surface A mm²	Contact surface in keeper B mm²	Contact force F kN	Screw dimension	Current carrying capacity A
100	4	75	18000	150	M12	30	3	115	4300	3000	150	M10	1600
						40	3	115	6000	4500	150	M10	2500
						60	3	115	9400	7200	200	M12	3480
150	4	75	27500	150	M12	60	3	115	9400	7200	200	M12	4000

12.8 Table 7 Flexible connectors with keepers for connection of tubes to flat terminal. See Figure 7

Conductor A, Tube						Flat terminal B			
Tube Diameter mm	Bolts N nos	Groove length L mm	Current carrying surface A mm²	Contact force F kN	Screw dimension	Flat terminal designation mm	Holes N nos	Thickness L mm	Current carrying capacity A
100	4	75	18000	150	M12	4-75 9-125	4 9	30 30	2500 3150
150	4	75	27500	150	M12	9-125 12-165	9 12	30 30	3150 4000

12.9 Table 8 Bolted connectors with two current carrying parts to for jointing tubes in free length. See Figure 8

Conductor A, Tube						Conductor B, Tube							
Tube Diameter mm	Bolts N nos	Groove length L mm	Current carrying surface A mm²	Contact force F kN	Screw dimension	Tube mm	Bolts N nos	Groove length L mm	Current carrying surface A mm²	Contact force F kN	Screw dimension	Bending moment Nm	Current carrying capacity A
100	4	75	19500	140	M12	100	4	75	19500	140	M12	9800	3480
150	4	75	30000	140	M12	150	4	75	30000	140	M12	28000	5150
250	4	75	50000	140	M12	250	4	75	105000	140	M12	86000	8890

The tube shall be encompassed by the joint on a length of 80% of tube diameter.

12.10 Table 9 Tensile strength, hardness and resistivity of aluminium for bolted connectors

	Tensile strength			Hardness	Resistivity
	Rp0,2 min. MPa	Rm min. MPa	A5 min. %	max. HBW	max. nΩm
Separate cast test bare	190	230	2		
Cast	180[1)]	200[1)]	1[1)]	75	50[2)]
Wrought	240	290	5	85	40[2)]

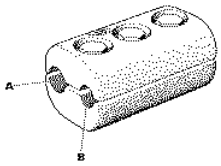
1) Values valid for machined test pieces manufactured from connector parts.

2) Values valid for current carrying parts.

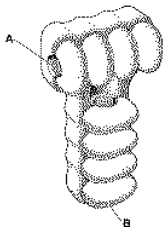
13 Figures

The Figures 1 to 8 represent an example of a typical bolted connector and is not necessarily in agreement to what is stipulated in Tables 1 to 8. Figure 9 to 15 are part of these technical guidelines.

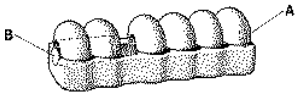
13.1 Figure 1 Bolted connectors with two current carrying parts to connect two parallel stranded conductors



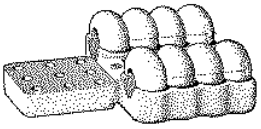
13.2 Figure 2 Bolted connector with keeper for T-connection of stranded conductors



13.3 Figure 3 Bolted connectors with keepers for connection of stranded conductors to cylindrical terminals

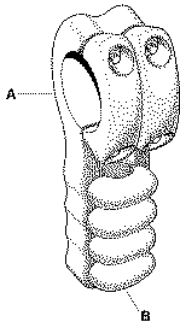


13.4 Figure 4 Bolted connectors with keepers for connection of stranded conductors to flat terminal[1]

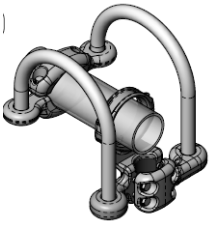


[1] For flat terminal thinner then given under point 15 a double sided connector should be used.

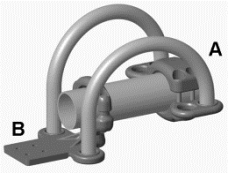
13.5 Figure 5 Bolted connectors with keepers for connection of stranded conductors to tubes



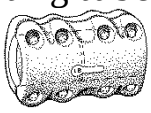
13.6 Figure 6 Flexible connectors with keepers for connection of tubes to cylindrical terminal



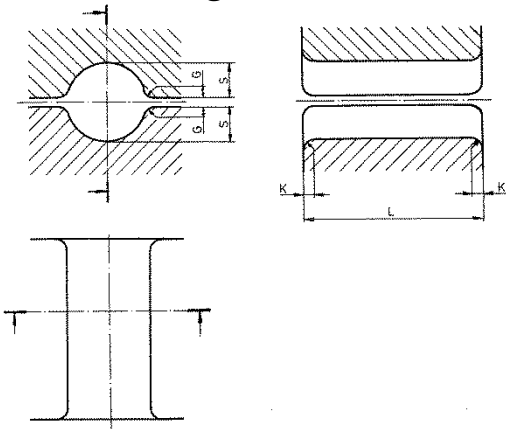
13.7 Figure 7 Flexible connectors with keepers for connection of tubes to flat terminal



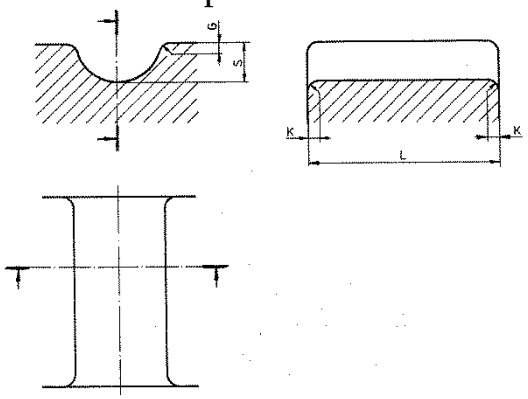
13.8 Figure 8 Bolted connectors with two current carrying parts to for jointing tubes in free length



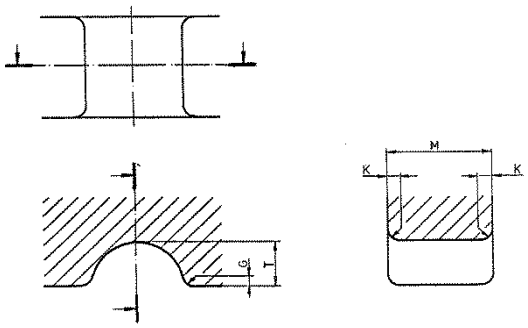
13.9 Figure 9 Current carrying contact surface in bolted connectors consisting of two current carrying parts



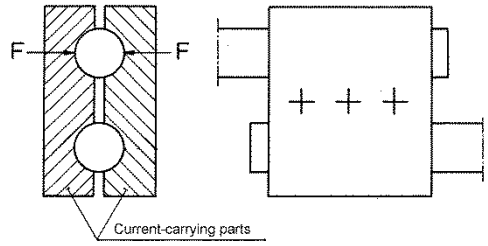
13.10 Figure 10 Current carrying contact surface in bolted connectors with keepers



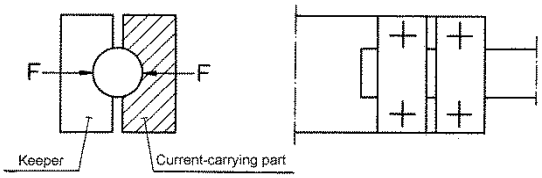
13.11 Figure 11 Contact surface in keepers for bolted connectors



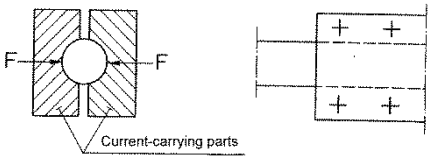
13.12 Figure 12 Contact force in bolted connectors consisting of two current carrying parts



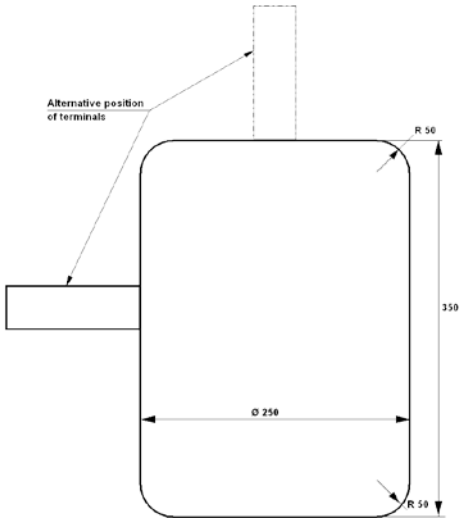
13.13 Figure 13 Contact force in bolted connectors with keepers



13.14 Figure 14 Contact force in bolted connectors consisting of two current carrying parts for connection of tubes



13.15 Figure 15 Apparatus test head for corona test of bolted connectors



14 Annex A - Aluminium tubes

These guidelines describe the requirements on extruded concentric aluminium tubs to be used as current carrying connectors for outdoor substations and deals with design and inspection. The guidelines intend to ensure that the conductor give a satisfactory function during the calculated technical lifetime for the substation and shall be used at purchase of aluminium tubs.

14.1 References

IEC 60114	Recommendation for heat treated aluminium alloy busbar material of the aluminium - magnesium - silicon type.
SS-EN 755-2	Aluminium and aluminium alloys – Extruded rod/bar, tube and profile –Part 2: Mechanical properties

14.2 Designation

The aluminium tube is designated by the nominal outside diameter in mm / inside diameter in mm and Al-tube.

14.3 Material

Aluminium tube shall be made of tempered aluminium alloy of AlMgSi-type, alloy EN AW-6101B T6 in accordance with SS-EN 755-2. This alloy shall meet the requirements according to IEC 60114.

14.4 Outside diameter and wall thickness

Aluminium tubes shall have outside diameter and wall thickness in accordance with 14.8

14.5 Length

Actual tube length and maximal support distances will be given in the order and the tubes shall meet all requirements given in 14.8

14.6 Straightness

The tubes shall meet the requirements for straightness as given in14.8

14.7 Design

Aluminium tube shall be extruded as seamless or porthole tube. If the aluminium tube have to be jointed due to manufacturing reasons following are applicable:

- Joint shall have the same electrical characteristics as non-jointed tube
- Joints, which not reduce the mechanical characteristics in statically or dynamically point of view may be situated at any distance of the tube.

- Welded joint, shall have an tensile strength of minimum 72% of the ultimate strength of the non-jointed tube material in accordance with IEC 60114, shall be situated in that way that at least 8000 mm of the tube in the middle of the of the span are non-jointed.

14.8 Table 14.1 Tube sizes and tolerances

Table 10:

Al-tube designation	Outer diameter			Wall thickness		Length	Oblique angle[5]	Straightness [6]		
	Nominal	Tolerance[1]	Roundness[2]	Min	Min average[3]	Tolerace[4]		<10 m	10-16 m	>16 m
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
100/88	100	±0,5	1,0	5,4	5,8	+25 -0	1,5	18	-	-
100/80	100	±0,5	1,0	9,2	9,7	+25 -0	1,5	18	-	-
150/136	150	±0,8	1,6	6,0	6,8	+25 -0	2,0	18	26	-
150/126	150	±0,8	1,6	10,8	11,6	+25 -0	2,0	18	26	-
250/236	250	±1,2	2,4	6,0	6,8	+30 -0	4,0	18	26	30
250/226	250	±1,2	2,4	10,8	11,6	+30 -0	4,0	18	26	30

1) Average diameter is a mean value of at least two perpendicular measurements at the same cross section.

2) Maximal difference between maximal and minimal diameter at the same cross section.

3) Average wall thickness is an arithmetical mean value of maximal end minimal measurement of the tube wall thickness.

4) For total tube length at +20°C.

5) The tubes shall be cut perpendicular to the central axes and with maximal oblique angle given in the table.

6) Straightness deviation shall not at any part of the tube be greater than 3 mm per running meter and the total straightness deviation shall not excide the value given in the table for the total length of the tube.

15 Annex B – Flat terminals for apparatus

Flat terminals for apparatus shall be used for connection of current carrying conductors with bolted connectors in outdoor substations. The guidelines intend to ensure that the terminals give a satisfactory function during the calculated technical.

Apparatus terminal of copper shall be tin-plated with at thickness of the tin of at least 50 μm.

Apparatus terminal of aluminium or aluminium alloy shall in principal have the same corrosion resistance as pure aluminium and shall not be sensitive to stress corrosion or boundary corrosion.

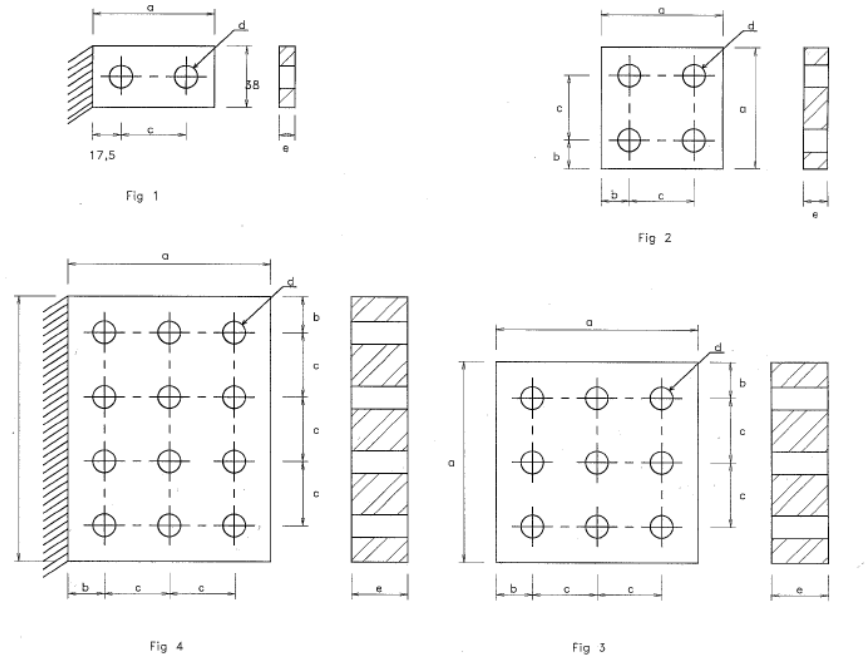
The distance between apparatus and given dimensions shall be at least 5 mm.

Apparatus terminal shall be determined from the apparatus rated current according to table 11:

Table 11

Designation	Holes number	Dimension mm	Thickness [1)] T min mm	Apparatus rated current One-sided A	Two-sided A
4-75	4	75 x 75	15	630 - 1250	
9-125	9	125 x 125	35	1600 - 3150	4000
12-165	12	125 x 165	35	4000	5000

15.1 Flat terminals[2]



Tabell 12:

Sizes (mm):							
Plate	Figur		a	b	c	d	e
2 - 75	1	2-hål	75	17,5	40	14	10
4 - 75	2	4-hål	75	17,5	40	14	15
9 - 125	3	9-hål	125	22,5	40	14	35
12 - 165	4	12-hål	125	22,5	40	14	35

[2] It should be possible to apply connector on both side of a terminal.

16 Annex C – Cylindrical terminals for apparatus

Cylindrical terminals for apparatus shall be used for connection of current carrying conductors with bolted connectors in outdoor substationsCylindrical terminal of copper is designated according to SEN 211012 with additional Cu.
Cylindrical terminal of aluminium is designated in accordance with table 12.

Apparatus terminal of copper shall be tin-plated with at thickness of the tin of at least 50 μm.

Apparatus terminal of aluminium or aluminium alloy shall in principal have the same corrosion resistance as pure aluminium and shall not be sensitive to stress corrosion or boundary corrosion. The distance between apparatus and given dimensions shall be at least 5 mm. Apparatus terminal shall be determined from the apparatus rated current according to table 13:

Designation	Diameter D Mm	Length L min mm	Apparatus rated current A
30 Al	30	125	1250
40 Al	40	125	1600
60 Al	60	125	2500

Figure 19 –Cylindrical terminal